

AMATEUR SATELLITE REPORT

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AO-10 IHU Crashes; May Be Repairable; Concern Expressed

After nearly three years of on-orbit performance, AO-10 has suffered a serious, if not fatal, malfunction. The central computer or Integrated Housekeeping Unit (IHU)—the computer that runs the whole satellite—experienced a major malfunction late Saturday, 17 May. The immediate prospects are that at least partial repairs can be made. The longer term prospects are somewhat more clouded.

On late Saturday, AO-10 users began to notice some odd symptoms. The telemetry mode did not switch from PSK to RTTY or CW. Moreover, the Mode B transponder was on during a perigee passage. It apparently was "locked" on. Only later was it learned the failure or "crash" of the IHU had put the satellite in a catatonic state.

When it became evident the spacecraft was not responding to command to shut off the Mode B transponder, an urgent appeal went out to all users to cease operation at once. The appeal was met with general, willing compliance although a few skeptics remained to be convinced the spacecraft emergency was authentic.

By Sunday morning a contingency team had been assembled and was analyzing symptoms, pouring over schematics, logic diagrams and computer program listings and evaluating actions to be taken. By a strange coincidence, all of the AO-10 command stations were planning to assemble in Colorado around 25 May to discuss plans for commanding Phase 3C, due for launch in late October. In fact Karl Meinzer, DJ4ZC was already in Boulder with an AMSAT DL team for P3C integration and thermal vacuum testing. Hans Peter Kuhlen, DK1YQ was enroute. Ian Ashley, ZL1AOX, Randy Smith, VE1SAT and Phil Karn, KA9Q were due to travel later in the week.

The contingency team quickly established that above all, the transponder had to be shut off to avoid draining the batteries to a dangerously low level. The only option for shutting off the transponder given the catatonic state of the IHU was a complete CPU reset. This was accomplished by ZL1AOX at about 2030 UTC on Sunday evening.

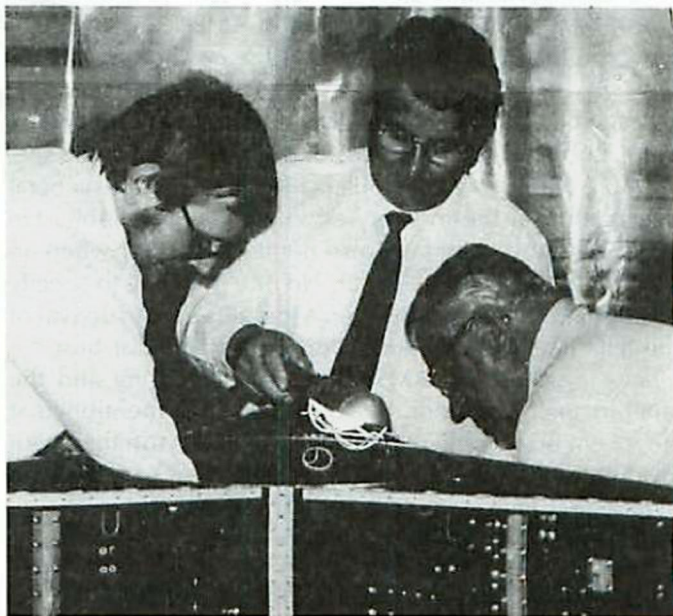
The spacecraft was in ideal position for ZL1AOX to work with it since it was positioned almost directly above Ian's Auckland QTH. He worked for several hours loading first the IPS compiler and later some of the higher level software

which runs the various functions. The software loaded easily but the IHU promptly crashed again after only 15 minutes of operation. ZL1AOX then opted to place the satellite in a relatively safe configuration until the next available orbit around 1700 UTC on Monday, the 19th.

On Monday Ian was able to reset and reload the computer and get the PSK Q block telemetry system running. He advised (see message) that the satellite would remain in that state for a few weeks while fault diagnosis and isolation proceeded.

Analysis of the fault is proceeding with experts from around the world considering the symptoms of the malfunction. Most are convinced the error is in the IHU memory and was caused by solar or cosmic radiation. The 16k memory chips are susceptible to the debilitating effects of exposure to radiation. The effects are cumulative so an overall degradation of the memory is suspected.

The immediate corrective action for ZL1AOX will be to maintain a watch over the spacecraft while software diagnostic routines are developed to identify faulty memory addresses. A new operating system will then be written to bypass the faulty area. Hopefully, the faulty area will be both



The German-American team works on P3C at Golden Colorado recently. (Left to right) Hans Peter Kuhlen, DK1YQ; Werner Haas, DJ5KQ; Joe Alaska, WB0RLY.

easily located and concentrated such that major reductions in the complexity of the software will not be required.

The software system designed into AO-10 is largely immune to radiation-induced software errors. Each computer byte contains extra bits which, when checked, indicates if the byte has been corrupted. The design of the error-correcting system is such that a single bit error can be detected and corrected and a two-bit error can be detected but not corrected.

Observers have reported unusually high solar activity in recent days. There is thus the possibility of a solar radiation-induced error. Errors of this type can range from *innocuous to fatal*. The CPU itself is a highly radiation-resistant COSMAC 1802 from Sandia, a special purpose rad-hard version of the RCA 1802 micro-processor.

The radiation hardness of the memory, while not up to the standards of the CPU, has been enhanced with the addition of a sandwich applique of tantalum and brass. Together the two materials, bonded to the top of each of the 16k RAM ICs, provide an extra margin of shielding beyond that provided by the spaceframe and IHU box. It has been known at least since 1980 that radiation hardness of the overall design was an important design criterion. However, no solid data has been available until now on the radiation resistance of these materials in this configuration.

Moreover, it has been noted with increasing concern by the engineering and command teams that the number of software "hits" has been remarkably high; notably higher than we had anticipated. Each time the error detection and correction system is obliged to correct a defective bit, a counter is incremented. The counter and its rate provide an index to the software upsets the IHU has experienced and thus provide an indirect measure of ionizing radiation *experience*. The counter has been measuring several hundred counts per week. This unusually high rate has caused some engineers to voice concern that overall spacecraft life might be limited by radiation hardness in this case rather than by battery vitality as has been the case in all prior OSCAR failures.

Karl Meinzer, DJ4ZC, President of AMSAT DL, a prime mover in the Phase 3 Project, says the current problem is survivable and there is a reasonable chance much functionality can be restored. But he hastens to add the current fault is the harbinger of a new class of problems we will be seeing more often now. It is emblematic, he says, of the general degradation of the memory all knew was inevitable. He adds that the current fault also points to the day when an unrecoverable fault will occur. No one is willing to specify when that will occur, however. Most agree that survival of the IHU is "iffy" and projections are difficult at best.

Jan King, W3GEY, AMSAT VP of Engineering and the other main collaborator on AO-10 and P3C, mentioned at the recent Board of Directors meeting in Dayton that, with the number of soft errors we are seeing on AO-10, it is well indeed that P3C is being prepared for launch.

Project Linkup Tests Proceeding

The Phase 2A test of Project Linkup was completed on schedule Saturday morning, 10 May at 1245 UTC. The FM

downlink signal on AO-10 Mode L was heard "full-quieting" by those monitoring across North America.

The Phase 2B test of Project Linkup was completed on schedule Saturday morning, 17 May at 1115 UTC.

The tests are designed to demonstrate bulletin delivery via terrestrial repeaters as relayed by AO-10 and gateway stations. Dates and times of further tests for the spring and summer period will be announced shortly. If tests continue positive, regular Mode L bulletin service may commence this autumn.

An information packet on Project Linkup is available free for a large, 9 by 11 inch SASE with \$0.56 postage affixed. Send your SASE to: Project Linkup, P.O. Box 177, Warwick, NY 10990.

Bulletin Indicates Plans

QST: OSCAR 10 OPERATIONAL REPORT
19th May 1986, at 23:45.

The computer on OSCAR 10 was reloaded with software between 19:38 and 20:37. The Telemetry Composer was activated at 20:56 UTC and Q Blocks were successfully received. The BCR-SERVICE software module was activated at 22:00. This will ensure that the batteries are kept well charged. All transponders will remain off until further notice. They will remain OFF at least 2 weeks while software diagnostics are performed to ascertain the locations of the suspected memory faults. Because of the minimum software being used, the RTTY and CW beacons will not be transmitted. Watch the PSK message blocks for latest information.

Ian Ashley, ZL1AOX

AMSAT GROUND CONTROL STATION 20/5/86

Mode-S Status Report

by Bill McCaa, KØRZ

Progress continues towards completion of the Mode-S transponder flight unit. KYØS, Chuck Hill, has completed the 41 and 42 MHz. oscillators and 3X multiplier stages. WBØWED, Steve Ernst, has completed the 18X multiplier. AAØL, Ray Ubrecken, has completed the S-band mixer. The flight S-RF box is being fabricated. John Morse, from the L5 Society, has completed the S-IF box and it is presently being painted. The i-f unit is the most behind schedule, and KØKE, Keith Ericson, has taken over the effort of completing this board. The RF PA has been received from N6CA, Chip Angle.

While testing the performance of the completed modules it was found that an additional filter and RF amplifier was necessary following the S-band mixer. This stage is now being constructed by WBØWED and should be completed this week.

Short Bursts

- A new AO-10 ground track overlay is now available. The overlay is scaled to be used with the ARRL OSCARlocator only. It is calibrated for maximum accuracy between June



Ron Vanke, K8YAH, right, explains his Mode L station to a visitor to Sunday's Beginner's Forum at Dayton.

and August, 1986 and is available free for a business sized SASE to: AO-10 Ground Track, c/o AMSAT, P.O. Box 27, Washington, DC 20044.

- An English translation of the new JAS-1 handbook published by JARL is now available from Project OSCAR. Send \$10 to:

JAS-1 Satellite Handbook
Project OSCAR, Inc
P.O. Box 1136
Los Altos, CA 94023

- Little news is available on ISKRA-4. It is not yet ready for transport to either MIR or SALYUT-7 for launch. This is not now expected for at least a further month. ISKRA-4 will carry both Mode-A and Mode-J transponders. The frequencies have recently been changed and the new ones are not yet known.

- A brand new software package is now available for the C-64. The exciting new features in Supertrak 64 include a highly detailed map display, ground track path, tracking up to 8 of 14 satellites in the menu and autocall of the QUIK-TRAK tabular program. Bob McGwier, N4HY, the designer of Supertrak 64 says that some special software hooks are built in to the package so it will run the soon-to-be-

available autotracking system from Encomm. The Supertrak package is now available at the AMSAT Software Exchange. be done before next Sunday.

New AO-10 Schedule Was Put Into Effect 16 May

On May 16, a new AO-10 operating schedule was placed in effect. Here is the new schedule:

Mode B	050 thru 119
Mode L	120 thru 136
Mode B	137 thru 199
OFF	200 thru 219
Mode B	220 thru 244
OFF	245 thru 049

Assuming the current problems with the IHU are overcome soon, this schedule, with possible minor adjustments, may be reimplemented.

The attitude will be 180 longitude and 0 latitude in the Bahn coordinate system. This is an ideal attitude for this season.

Watch the beacons for late word on activities planned.

ZRO Test Features First Mode L Trial

The ZRO Test was held Sunday 11 May as follows.

Mode L 1200 UTC on 436.450 MHz
Mode B 1530 UTC on 145.830 MHz

The Mode L test was the first one held. It went smoothly for a first effort. After the test was complete, values were computed to normalize the particular test at *sub-apogee* to the projected apogee values. This was necessary to compensate for the reduced path loss encountered when running the test at reduced altitude. The difference between 29,000 and 40,000 km accounts for 3 dB difference in 436 MHz downlink path loss. That is, the frame of reference is the strength of the beacon when heard at apogee. Apogee is at about 40,000 km and the recent test was at sub-apogee; 29,000 km. Thus 3dB or one "Z" unit must subtracted. So if you heard the Z7 level, in order to normalize to apogee, you must subtract one Z-unit and you earned a Z6 rating.

The Mode B test might be analogously derated but the spin modulation was so bad the scores will be allowed to stand with no derating to normalize to apogee path losses.

Phase 3C Status #13, 12 May, 1986

by Joe Flaska, WBØRLY, Colorado Area Coordinator

Sunday's work session, the last before the DL team's arrival was a long one, and wasn't over until well after darkness arrived.

Work was done on the Liquid Ignition Unit and it appears the problems are finally under control. The connector for the LIU enclosure is yet to be wired. Hopefully, that will be done before next Sunday.

A review of the Thermal-Vacuum test scenario was done. Dave, WD0HHU, of Martin-Marietta now knows what is within AMSAT limitations. The test continues to be scheduled for 26 May.

Significant progress was made on the Mode S i-f and control board by K0RZ, Bill and K0KE, Eric. Some problems had recently surfaced and appeared quite serious. However, a long brainstorming session Sunday seems to have finally broken through the logjam. A report from Bill on Sunday indicates he's confident the transponder will fly on P3C.

The AMSAT lab is limited in size; about 24' square. To provide more work room for the DL team all unneeded items were removed. The shipping container for P3C was picked up by KA0CZW, Bill and taken to his home for cleaning and storage until needed again. Extra work tables were provided for the integration activities about to begin.

Work on the tank bottom area was done. For this, the satellite was turned on its back and the Separation Push Pads were installed and wired. All other wiring in this area was completed and the unit was then inverted to its proper

mode. At that point W3GEY spoke the magic and long sought words "We have a satellite". True, one relay is still to be wired, but except for that, the structure is ready for transponders.

A startup of the flight computer reveals all is in order.

The Worklog at the lab now shows 1456 man-hours.

The AMSAT DL team is scheduled to arrive later today, 12 May, on a direct flight from Frankfurt. Accommodations for them are at a motor inn less than 3 miles from the lab. Transportation awaits them at the airport and we believe all is in order for their comfort. It's our aim for their stay in Colorado to be a good one. Good weather has been ordered for the next 3 weeks. (It usually is in May).

WA0IQN, Don, drives from Golden to the Martin-Marietta plant daily via a mostly residential route. He reports the drive involves 13 miles and about 30 minutes, and he's furnished a map. Members of the lab construction team will drive the route within the week to verify that it could be used efficiently once the Thermal-Vacuum test begins.

Orbit Predictions

Satellite	OSCAR-10
Catalog number	14129
Epoch time:	86121.64800534
Thu May 1 15:33:07.661 1986 UTC	
Element set:	241
Inclination:	26.4347 deg
RA of node:	82.2988 deg
Eccentricity:	0.6015522
Arg of perigee:	106.9735 deg
Mean anomaly:	324.0814 deg
Mean motion:	2.05850416 rev/day
Decay rate:	4.8e-07 rev/day ²
Epoch rev:	2168
Semi major axis	26105.958 km
Anom period:	699.537085 min
Apogee:	35435.786 km
Perigee:	4027.594 km
Ref perigee:	3042.69647446
Thu May 1 16:42:55.393 1986 UTC	
Translate freq	581.0047 MHz
Invert:	1
Beacon:	145.8090 MHz

Satellite	mir
Catalog number	16609
Epoch time:	86134.92200850
Wed May 14 22:07:41.534 1986 UTC	
Element set:	138
Inclination:	51.6153 deg
RA of node:	46.9327 deg
Eccentricity:	0.0009165
Arg of perigee:	138.2850 deg
Mean anomaly:	221.8939 deg
Mean motion:	15.77673852 rev/day
Decay rate:	0.00010786 rev/day ²
Epoch rev:	1327
Semi major axis	6715.688 km
Anom period:	91.273618 min
Apogee:	349.516 km
Perigee:	337.206 km
Ref perigee:	3055.94632455
Wed May 14 22:42:42.441 1986 UTC	
Beacon:	143.6250 MHz

Satellite	Salyut-7
Catalog number	13138
Epoch time:	86134.86928230
Wed May 14 20:51:45.990 1986 UTC	
Element set:	167
Inclination:	51.6236 deg
RA of node:	47.3419 deg
Eccentricity:	0.0005451
Arg of perigee:	148.7287 deg
Mean anomaly:	211.4261 deg
Mean motion:	15.77154875 rev/day
Decay rate:	5.129e-05 rev/day ²
Epoch rev:	23450
Semi major axis	6717.160 km
Anom period:	91.303652 min
Apogee:	346.218 km
Perigee:	338.895 km
Ref perigee:	3055.89545001
Wed May 14 21:29:26.880 1986 UTC	

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Apogee:	346.218 km
Perigee:	338.895 km
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Wed May 14 21:29:26.880 1986 UTC	

Reference Orbits

Sunday May 18, 1986

Satellite	OSCAR-9
Catalog number	16609
Epoch time:	86134.92200850
Wed May 14 22:07:41.534 1986 UTC	
Element set:	138
Inclination:	51.6153 deg
RA of node:	46.9327 deg
Eccentricity:	0.0009165
Arg of perigee:	138.2850 deg
Mean anomaly:	221.8939 deg
Mean motion:	15.77673852 rev/day
Decay rate:	0.00010786 rev/day ²
Epoch rev:	1327
Semi major axis	6715.688 km
Anom period:	91.273618 min
Apogee:	349.516 km
Perigee:	337.206 km
Ref perigee:	3055.94632455
Wed May 14 22:42:42.441 1986 UTC	
Beacon:	143.6250 MHz

AO-10 Apogees: The first apogee of each UTC day with SSP.

Day	Date	Time	Latitude	Longitude	Arg.Per.
Sun	18May	10:56:53	24.5s	26.7w	111.6
Mon	19May	10:15:56	24.4s	17.3w	111.9
Tue	20May	09:35:01	24.4s	7.9w	112.1
Wed	21May	08:54:04	24.3s	358.5w	112.4
Thu	22May	08:13:08	24.3s	349.1w	112.6
Fri	23May	07:32:12	24.2s	339.7w	112.9
Sat	24May	06:51:16	24.2s	330.3w	113.1

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